CLAIMS

What is claimed is:

1. A substantially homogeneous nanocomposite material, comprising:
an inorganic oxide constituent;
a hydrophilic polymer constituent; and
a metal ion sequestration constituent, wherein the hydrophilic polymer constituent and the inorganic oxide constituent form an interpenetrating network with each other.

2. The nanocomposite material of claim 1, wherein the inorganic oxide constituent is a metal oxide.

3. The nanocomposite material of claim 1, wherein the inorganic oxide constituent is selected from the group consisting of silicon dioxide, aluminum oxide, titanium oxide, zirconium oxide, boron oxide, and combinations thereof.

4. The nanocomposite material of claim 1, wherein the hydrophilic polymer constituent is selected from the group consisting of polyacrylonitrile, polyethyleneoxide, polyethylene glycol, polyvinyl acetate, polyvinyl alcohol, and combinations thereof.

5. The nanocomposite material of claim 1, wherein the metal ion sequestration constituent is formulated for chemically binding with cesium metal ions.

6. The nanocomposite material of claim 1, wherein the metal ion sequestration constituent is selected from the group consisting of ammonium molybdophosphate, phosphonopyridine n-oxides, thiophosphinic acid, dithiophosphinic acid, and combinations thereof.

7. The nanocomposite material of claim 1, wherein the metal ion sequestration constituent is substantially uniformly distributed throughout the nanocomposite material.

8. The nanocomposite material of claim 1, wherein the inorganic oxide constituent is selected from the group consisting of silicon dioxide, aluminum oxide, titanium oxide, zirconium oxide, boron oxide, and combinations thereof;

wherein the hydrophilic polymer constituent is selected from the group consisting of polyacrylonitrile, polyethyleneoxide, polyethylene glycol, polyvinyl acetate, polyvinyl alcohol, and combinations thereof; and

wherein the metal ion sequestration constituent is selected from the group consisting of ammonium molybdophosphate, phosphonopyridine n-oxides, thiophosphinic acid, dithiophosphinic acid, and combinations thereof.

9. A method of making a nanocomposite material comprising:

providing a mixture of a solvated hydrophilic polymer and an inorganic precursor;

adding a metal ion sequestration constituent to the mixture; and

forming the mixture of the solvated hydrophilic polymer, the inorganic precursor, and the metal ion sequestration constituent into a nanocomposite material.

10. The method according to claim 9, further comprising selecting the inorganic precursor to be metal alkoxide.

11. The method according to claim 10 further comprising selecting the inorganic precursor from the group consisting of silicon alkoxides, titanium alkoxides, zirconium alkoxides, aluminum alkoxides, and combinations thereof.

12. The method according to claim 10, further comprising selecting the metal alkoxide from the group consisting of tetraethylorthosilicate, tetraisopropoxyorthotitanate, zirconium n-butoxide, aluminum tri-sec butoxide, and combinations thereof.

13. The method according to claim 9, further comprising selecting the metal ion sequestration constituent from the group consisting of ammonium molybdophosphate, phosphonopyridine n-oxides, thiophosphinic acid, dithiophosphinic acid, and combinations thereof.

14. The method according to claim 9, further comprising selecting the hydrophilic polymer from the group consisting of polyacrylonitrile, polyethyleneoxide, polyethylene glycol, polyvinyl acetate, polyvinyl alcohol, and combinations thereof.

15. The method according to claim 9, further comprising selecting the inorganic precursor from the group consisting of silicon alkoxides, titanium alkoxides, zirconium alkoxides, aluminum alkoxides, and combinations thereof;
selecting the hydrophilic polymer from the group consisting of polyacrylonitrile, polyethyleneoxide, polyethylene glycol, polyvinyl acetate, polyvinyl alcohol, and combinations thereof; and
selecting the metal ion sequestration constituent from the group consisting of ammonium molybdophosphate, phosphonopyridine n-oxides, thiophosphinic acid, dithiophosphinic acid, and combinations thereof.

16. A permeable reactive barrier system comprising:
a membrane disposed in a flow path of water within the ground, the membrane formed from a substantially homogeneous nanocomposite material, comprising:
an inorganic oxide constituent;
a hydrophilic polymer constituent; and
a metal ion sequestration constituent, wherein the hydrophilic polymer constituent and the inorganic oxide constituent form an interpenetrating network with each other.

17. The permeable reactive barrier system of claim 16, wherein the inorganic oxide constituent is a metal oxide.

18. The permeable reactive barrier system of claim 16, wherein the inorganic oxide constituent is selected from the group consisting of silicon dioxide, aluminum oxide, titanium oxide, zirconium oxide, boron oxide, and combinations thereof.

19. The permeable reactive barrier system of claim 16, wherein the hydrophilic polymer constituent is selected from the group consisting of polyacrylonitrile, polyethyleneoxide, polyethylene glycol, polyvinyl acetate, polyvinyl alcohol, and combinations thereof.

20. The permeable reactive barrier system of claim 16, wherein the metal ion sequestration constituent is formulated for chemically binding with cesium metal ions.

21. The permeable reactive barrier system of claim 16, wherein the metal ion sequestration constituent is selected from the group consisting of ammonium molybdophosphate, phosphonopyridine n-oxides, thiophosphinic acid, dithiophosphinic acid, and combinations thereof.

22. The permeable reactive barrier system of claim 16, wherein the metal ion sequestration constituent is substantially uniformly distributed throughout the nanocomposite material.

23. The permeable reactive barrier system of claim 16, wherein the membrane is disposed within a vadose region of the ground.

24. The permeable reactive barrier system of claim 16, wherein the membrane is disposed in an excavated trench within the ground.

25. The permeable reactive barrier system of claim 24, wherein the membrane is disposed in a portion of the water table within the ground.

26. The permeable reactive barrier system of claim 16, further comprising substantially impermeable walls positioned and located within the ground to direct flow of groundwater toward the membrane.

27. The permeable reactive barrier system of claim 26, wherein the substantially impermeable walls are disposed at an angle greater than zero degrees in relation to the membrane.

28. The permeable reactive barrier system of claim 26, wherein the substantially impermeable walls are disposed in a portion of the water table.

29. The permeable reactive barrier system of claim 16, wherein the membrane exhibits a permeability substantially the same as hydraulic conductivity of the ground the membrane is placed within.

30. The permeable reactive barrier system of claim 16, wherein the inorganic oxide constituent is selected from the group consisting of silicon dioxide, aluminum oxide, titanium oxide, zirconium oxide, boron oxide, and combinations thereof;
wherein the hydrophilic polymer constituent is selected from the group consisting of polyacrylonitrile, polyethyleneoxide, polyethylene glycol, polyvinyl acetate, polyvinyl alcohol, and combinations thereof; and
wherein the metal ion sequestration constituent is selected from the group consisting of ammonium molybdophosphate, phosphonopyridine n-oxides, thiophosphinic acid, dithiophosphinic acid, and combinations thereof.

31. The permeable reactive barrier system of claim 16, wherein the membrane comprises a plurality of discrete particles of the nanocomposite material.

32. A method of making a permeable reactive barrier system comprising:
providing a membrane formed from a substantially homogeneous nanocomposite material, comprising:

an inorganic oxide constituent;

a hydrophilic polymer constituent; and

a metal ion sequestration constituent, wherein the hydrophilic polymer constituent and the inorganic oxide constituent form an interpenetrating network with each other; and

disposing the membrane within the ground and in a flow path of water within the ground.

33. The method according to claim 32, further comprising selecting the inorganic oxide constituent to be a metal oxide.

34. The method according to claim 32, further comprising selecting the inorganic oxide constituent from the group consisting of silicon dioxide, aluminum oxide, titanium oxide, zirconium oxide, boron oxide, and combinations thereof.

35. The method according to claim 32, further comprising selecting the hydrophilic polymer constituent from the group consisting of polyacrylonitrile, polyethyleneoxide, polyethylene glycol, polyvinyl acetate, polyvinyl alcohol, and combinations thereof.

36. The method according to claim 32, further comprising formulating the metal ion sequestration constituent for chemically binding with cesium metal ions.

37. The method according to claim 32, further comprising selecting the metal ion sequestration constituent from the group consisting of ammonium molybdophosphate, phosphonopyridine n-oxides, thiophosphinic acid, dithiophosphinic acid, and combinations thereof.

38. The method according to claim 32, further comprising formulating the nanocomposite material to have the metal ion sequestration constituent substantially uniformly distributed throughout it.

39. The method according to claim 32, further comprising selecting the inorganic oxide constituent from the group consisting of silicon dioxide, aluminum oxide, titanium oxide, zirconium oxide, boron oxide, and combinations thereof;
selecting the hydrophilic polymer from the group consisting of polyacrylonitrile, polyethyleneoxide, polyethylene glycol, polyvinyl acetate, polyvinyl alcohol, and combinations thereof; and
selecting the metal ion sequestration constituent from the group consisting of ammonium molybdophosphate, phosphonopyridine n-oxides, thiophosphinic acid, dithiophosphinic acid, and combinations thereof.

40. The method according to claim 32, further comprising disposing the membrane within a vadose zone of the ground.

41. The method according to claim 32, further comprising injecting precursor materials of the nanocomposite material into the ground to form the membrane.

42. The method according to claim 32, further comprising forming the membrane by injecting a slurry into the ground, the slurry comprising a plurality of discrete particles of the nanocomposite dispersed in a liquid.

43. The method according to claim 42, further comprising selecting the liquid to be water.

44. The method according to claim 32, further comprising excavating a trench in the ground configured to receive the membrane therein.

45. The method according to claim 44, further comprising placing the membrane within the trench.

46. The method according to claim 32, further comprising excavating additional trenches in the ground adjacent the membrane at an angle greater than zero degrees in relation to the membrane.

47. The method according to claim 46, further comprising disposing a substantially impermeable material within the additional trenches.

48. The method according to claim 32, further comprising injecting substantially impermeable wall members within the ground adjacent the membrane.

49. A method of treating groundwater comprising:
flowing contaminated groundwater having metal ion contaminants into a permeable substantially homogeneous nanocomposite material, the permeable substantially homogeneous nanocomposite material, comprising:

an inorganic constituent;

a hydrophilic polymer constituent; and

a metal ion sequestration constituent, wherein the hydrophilic polymer constituent and the inorganic oxide constituent form an interpenetrating network with each other;

binding a portion of the metal ion contaminants present in the contaminated groundwater to the permeable substantially homogeneous nanocomposite material to produce treated groundwater, the treated groundwater having a lower amount of metal ion contaminants relative to the contaminated groundwater; and

flowing the treated groundwater out of the permeable substantially homogeneous nanocomposite material.

50. The method according to claim 49, further comprising disposing the permeable substantially homogeneous nanocomposite material within a vadose zone of the ground.

51. The method according to claim 49, further comprising disposing a portion of the permeable substantially homogeneous nanocomposite material within the water table within the ground.

52. The method according to claim 49, further comprising selecting the inorganic oxide constituent to be a metal oxide.

53. The method according to claim 49, further comprising selecting the inorganic oxide constituent from the group consisting of silicon dioxide, aluminum oxide, titanium oxide, zirconium oxide, boron oxide, and combinations thereof.

54. The method according to claim 49, further comprising selecting the hydrophilic polymer constituent from the group consisting of polyacrylonitrile, polyethyleneoxide, polyethylene glycol, polyvinyl acetate, polyvinyl alcohol, and combinations thereof.

55. The method according to claim 49, further comprising formulating the metal ion sequestration constituent for chemically binding with cesium metal ions.

56. The method according to claim 49, further comprising selecting the metal ion sequestration constituent from the group consisting of ammonium molybdophosphate, phosphonopyridine n-oxides, thiophosphinic acid, dithiophosphinic acid, and combinations thereof.

57. The method according to claim 49, further comprising chemically binding the metal ion contaminants to the permeable substantially homogeneous nanocomposite material.

58. The method according to claim 49, wherein the metal ion contaminants include cesium metal ions.

59. The method according to claim 49, further comprising selecting the inorganic oxide constituent from the group consisting of silicon dioxide, aluminum oxide, titanium oxide, zirconium oxide, boron oxide, and combinations thereof;
selecting the hydrophilic polymer from the group consisting of polyacrylonitrile, polyethyleneoxide, polyethylene glycol, polyvinyl acetate, polyvinyl alcohol, and combinations thereof; and
selecting the metal ion sequestration constituent from the group consisting of ammonium molybdophosphate, phosphonopyridine n-oxides, thiophosphinic acid, dithiophosphinic acid, and combinations thereof.